

Total Occlusion of the Left Main Coronary Artery: The Coronary Artery Surgery Study (CASS) Experience

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Total occlusion of the left main coronary artery was confirmed on review of the coronary angiograms in 12 (0.06 percent) of the 20,197 patients entered into the Coronary Artery Surgery Study (CASS) before coronary arterial surgery. Clinical features alone could not distinguish the patients with total occlusion of the left main coronary artery from those enrolled in the CASS with subtotal stenosis of this vessel. The right coronary artery had a stenosis greater than or equal to 70 percent of luminal diameter in 7 of the 12 patients. Collateral flow to the left coronary artery was defined as "substantial" or "limited" based on the presence or absence of clear visualization of the main channel of either the left anterior descending or left circumflex coronary artery during coronary angiography. Of the eight patients with "substantial" collateral flow, one (13 percent) had an aneurysmal or dyskinetic left ventricular wall segment, whereas all (100 percent) of the three patients with "limited" collateral flow had dyskinesia or an aneurysm ($p < 0.05$). Seven patients underwent coronary bypass graft surgery; 6 (86 percent) of these patients were living at their most recent follow-up, a mean of 46 months after entry into the CASS. Two of these patients continued to have angina pectoris. Five patients did not undergo coronary bypass grafting and 2 (40 percent) were still alive at their most recent follow-up, a mean of 45 months after entry into the CASS. One of these patients had angina pectoris. The difference in survival between the medical and surgical groups was not statistically significant.

This study indicates that patients with total occlusion of the left main coronary artery are uncommon and cannot be distinguished by presenting features alone from patients having subtotal stenosis of the left main coronary artery. "Substantial" coronary collateral blood flow is associated with better left ventricular wall motion than is "limited" collateral flow. Prolonged survival and lessening of symptoms may occur after coronary bypass grafting although long-term survival is possible without it.

Total occlusion of the left main coronary artery is rarely demonstrated with coronary angiography. Previous reports^{1,2} have indicated that the risk of death in patients who have subtotal left main coronary arterial stenosis is related to the severity of luminal narrowing. Because complete occlusion of the left main coronary artery is the ultimate degree of stenosis of this vessel, the clinical course of patients with this lesion is of interest. Although 53 patients with total occlusion of the left main coronary artery believed to be caused by atherosclerosis have been described to date, each of the reported series³⁻¹⁷ has had a small number of patients. The large number of patients in the Coronary Artery Surgery Study (CASS) provides an opportunity to delineate the frequency of total left main coronary occlusion, to describe further the clinical and angiographic patterns of this entity and to make observations regarding therapy.

Methods

Patients: The CASS is a multicenter project designed to define the long-term results of medical and surgical therapy in well defined subsets of patients with

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coronary artery disease. Comprising the study are 15 participating clinical sites and a coordinating center (see Appendix). At each clinical site all consenting patients who underwent cardiac catheterization for suspected or proved coronary artery disease were enrolled in the CASS. Patients found to have heart disease other than coronary artery disease were excluded. Patients with normal coronary arteries were not excluded.

Details of data acquisition and storage in the CASS have previously been described in detail.^{18,19} In brief, the clinical information for the CASS patients was obtained and systematically recorded by staff cardiologists at the various clinical centers. Follow-up information was obtained at yearly intervals and recorded by staff cardiologists or specially trained research assistants. The clinical and follow-up data were stored in computerized records.

For this study the CASS records were retrieved and analyzed for the patients diagnosed as having a totally occluded left main coronary artery. In addition, medical records of the patients with this entity were obtained from the patients' physicians or hospitals and were examined. The cumulative CASS registry, acquired between August 1975 and June 1979, contained 20,197 patients who had not undergone coronary surgery at the time of entry into the study. In this group 18 patients were coded as having a totally occluded left main coronary artery. Coronary and left ventricular cineangiograms of each of these patients were reviewed in detail by two of the three principal authors. Coronary anatomy and left ventricular wall motion were analyzed without reference to the original interpretation made at the time of entry into the CASS. Two patients were found to have extremely high grade stenosis of the left main coronary artery but did not satisfy the criteria for total occlusion and were thus excluded from this study. Also excluded were one patient with total occlusion of both the proximal left anterior descending coronary artery and the left circumflex coronary artery but a patent left main coronary artery, one patient whose occlusion was in the proximal left anterior descending coronary artery, a patient who had a single coronary artery arising from the right coronary sinus and one patient whose films were lost. Thus 12 patients or 0.06 percent of those enrolled in the CASS before any coronary surgery had confirmed total occlusion of the left main coronary artery. These 12 patients form the present

study group and constitute the largest reported series of this entity.

In addition there were 1,495 patients enrolled in the CASS with 50 to 99 percent stenosis of the left main coronary artery. The clinical data in this group were analyzed and compared with data in the group having total occlusion of the left main coronary artery.

Clinical and angiographic assessment: Clinical functional classification of angina pectoris was made using the criteria of the Canadian Cardiovascular Society.²⁰ Unstable angina was defined as onset of chest pain less than 2 months before entry into the CASS, a changing pattern of pain, angina at rest, or the occurrence of an episode of chest pain lasting longer than 30 minutes associated with ischemic electrocardiographic changes with no evidence of acute myocardial infarction.

Coronary stenosis was graded as a percent reduction of internal diameter. For the 12 patients with total occlusion of the left main coronary artery, the final assessment of coronary narrowing was reached by consensus of the principal authors.

Left ventricular wall motion was assessed from cineangiograms of the left ventricle which were obtained in 11 of the 12 patients. The right anterior oblique view was obtained in all 11 patients and the left anterior oblique view in 5. The left ventricular wall outline in each view was divided into five segments and each segment was analyzed separately. Hypokinesia of a wall segment was defined as reduced systolic contraction of the segment, akinesia as no systolic movement of the segment, dyskinesia as an outward bulge of the segment in systole and aneurysm as a persistent diastolic outline deformity in the left ventricular wall segment plus systolic akinesia or dyskinesia involving that segment.

Statistical analysis: Continuous variables were compared utilizing the nonpaired Student's *t* test. Dichotomous variables were compared utilizing Fisher's exact test.

Results

Clinical data (Table I): The mean age of the 12 patients with complete occlusion of the left main coronary artery was 58.8 years (range 44 to 80). Ten patients were male and two were female. All patients were white.

TABLE I

Clinical Features of 12 Patients With Total Occlusion of the Left Main Coronary Artery

Case	Age (yr) & Sex	Angina			History of				Serum Chol (mg/dl)
		C.C.S. Class*	Unstable	Duration (yr) [†]	MI	CHF	Cardiac Arrest	Risk Factors	
1	53M	III	—	0.3	—	—	—	Cig., FH	?
2	46M	III	—	0.4	—	—	—	Cig.	192
3	74M	IV	—	3.0	+	+	—	HBP	?
4	62F	II	—	9.0	—	—	—	Cig., HBP, FH	267
5	80M	IV	—	6.0	—	—	—	Cig.	170
6	47M	IV	+	2.5	+	—	—	Cig.	155
7	44M	No angina	—	—	—	—	—	Cig., FH	246
8	55M	IV	+	9.0	+	—	—	Cig.	277
9	72M	III	—	14.0	+	+	—	Cig., HBP	?
10	68M	III	—	3.0	+	+	—	Cig., HBP	?
11	45M	III	+	0.1	—	—	—	Cig.	298
12	60F	IV	+	1.5	+	—	—	Cig., HBP, FH	398

* Functional classification of angina at time of enrollment in CASS. [†] Time from onset of angina to enrollment in CASS.

C.C.S. = Canadian Cardiovascular Society; CHF = congestive heart failure; Chol = cholesterol; Cig. = cigarette use; FH = family history; HBP = high blood pressure; MI = myocardial infarction; ? = not reported; + = present; — = absent.

TABLE II

Clinical Characteristics of Patients With Total and Subtotal Stenosis of the Left Main Coronary Artery (LMCA)

	100% LMCA (n = 12)	50–99% LMCA (n = 1495)
Angina pectoris:	11 (92%)	(90%)
Class I	0	(4%)
Class II	1 (8%)	(21%)
Class III	5 (42%)	(36%)
Class IV	5 (42%)	(22%)
Unrelated to exertion	0	7%
Unstable	4 (33%)	36%
Duration of chest pain (yr)	4.4 ± 1.3	5.0 ± 0.1
History of		
Myocardial infarction	6 (50%)	(41%)
Congestive heart failure	3 (25%)	(11%)
Cardiac arrest	0	(4%)

Risk factor analysis revealed that 11 patients had smoked cigarettes, 5 had a history of hypertension, none had a history of diabetes mellitus and 4 had a family history of coronary artery disease. Total serum cholesterol averaged 250 mg/dl in the eight patients for whom values were reported.

Presenting complaints and certain historical features in the group of patients with total left main coronary occlusion as well as those of the larger group of patients with subtotal left main coronary stenosis are summarized in Table II. Although most patients in both groups had marked angina pectoris there were no sig-

nificant differences between the two groups in prevalence, severity or duration of the angina or in previous history of myocardial infarction, congestive heart failure or cardiac arrest.

Physical examination generally revealed normal findings. Except for a third heart sound in one patient (Case 9), there was no evidence of left or right heart failure at the time of entry into the study. Chest radiography revealed cardiomegaly in five patients.

Cardiac catheterization and angiographic data:

The extent of stenosis in the right, left anterior descending and left circumflex coronary arteries in the 12 patients with total occlusion of the left main coronary artery are listed in Table III. Coronary angiography revealed visible calcium in the left main coronary artery in 9 of the 12 patients in whom this vessel was occluded. A cul-de-sac greater than 2 mm in length was found in 10 of these 12 patients. Figure 1 shows two examples of the coronary angiographic appearance of the left main coronary artery. The first frame (Fig. 1, top, Case 4) reveals tapering of the lumen of the vessel down to a complete occlusion. In contrast, the left coronary cusp injection from another study (Fig. 1, bottom, Case 1), shows complete occlusion of the ostium of the left main coronary artery.

The right coronary artery in all cases in this series was dominant (that is, extended into the left atrioventricular groove) and supplied the intercoronary collateral vessels that filled the left coronary arteries. Figure 2 shows an example of a large right coronary artery with

TABLE III

Coronary and Left Ventricular Angiographic Findings in 12 Patients With Total Occlusion of the Left Main Coronary Artery

Case	Degree of Stenosis in Other Coronary Arteries*			Left Ventricle	
	Right	Left Anterior Descending	Left Circumflex	Pressure (mm Hg)	Worst Abnormality of Wall Motion
1	80% prox, 20% dist, 90% PDA, 60% PLB, 80% R marg	90% mid	Prox not vis.	100/15	Mod Hypokinesia
2	30% prox, 30% mid, 30% dist, 30% R marg	Prox not vis., mid & dist small size	Prox & dist poorly vis.	†	
3	30% prox, 80% R marg	90% prox, 90% mid	95% prox, 70% dist, 80% 1st L marg	100/25	Aneurysm
4	50% PDA	100% prox, 80% mid, 80% dist	No lesions	125/18	Akinesia
5	50% prox, 70% mid, 95% PDA	Not vis.	Not vis.	100/6	Dyskinesia
6	95% mid	Poorly vis.	Not vis.	85/25	Dyskinesia
7	20% mid	Prox not vis.	Not vis. except 1st L marg	120/10	Akinesia
8	100% dist, 100% PLS	Prox not vis., 50% mid	Not vis. except 1st L marg	105/5	Mod Hypokinesia
9	Multiple discrete aneurysmal dilations	No lesions	No lesions	225/35	Akinesia
10	50% prox, 70% mid	Poorly vis.	Prox not vis., dist poorly vis.	115/30	Aneurysm
11	20% prox, 20% mid	No lesions	No lesions	135/23	WNL
12	90% prox, 80% mid, 60% dist, 10% PDA, 70% PLB	Prox not vis.	Poorly vis.	125/24	Akinesia

* Percentages refer to degree of luminal narrowing. † No left ventriculogram performed.

Dist = distal segment; L marg = left (obtuse) marginal branch artery; mid = middle segment; mod = moderate; PDA = posterior descending artery; PLB = posterolateral branch artery; PLS = posterolateral segment artery; prox = proximal segment; R marg = right (acute) marginal branch artery; vis. = visualized; WNL = within normal limits.

rich collateral flow (Case 2). The right coronary artery had a stenosis of 70 percent or greater in 7 of the 12 patients (stenosis in the main channel in 6 and in an acute marginal branch that supplied collateral channels to the left anterior descending coronary artery in 1). The left coronary arterial branches had clearly observed stenoses of 70 percent or greater in 3 of the 12 patients, in 2 there appeared to be no significant stenoses, and in the other 7, the left-sided vessels were not visualized well enough to describe precisely the degree of stenosis.

Left ventricular contrast injection was made in 11 of the 12 patients (Table III). The left ventricular contraction pattern appeared normal in one patient.

Among the remaining 10, the most severe abnormality of wall motion was moderate hypokinesia in two patients, akinesia in 4 and dyskinesia or aneurysm in 4. Mitral regurgitation was not found in any patient. The left ventricular end-diastolic pressure averaged 20 mm Hg.

The relation between coronary collateral circulation and left ventricular wall motion was analyzed. "Substantial" collateral flow was said to exist when at least part of the main channel of either the left anterior descending or the left circumflex coronary artery was well seen. "Limited" collateral flow was said to be present when no part of either main channel could be well seen. Among the eight patients with "substantial" collateral

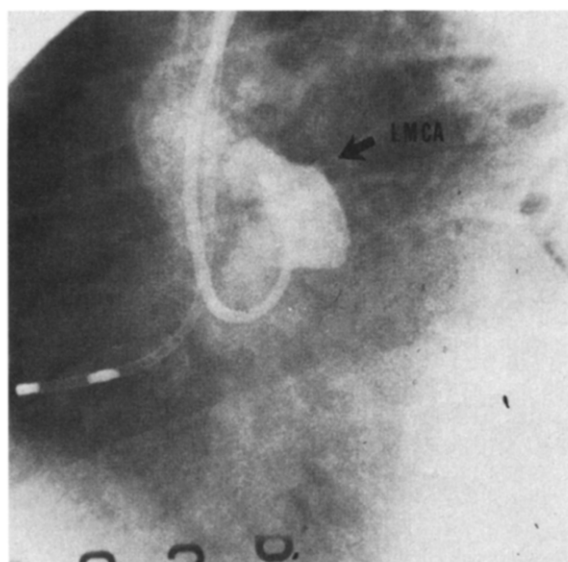
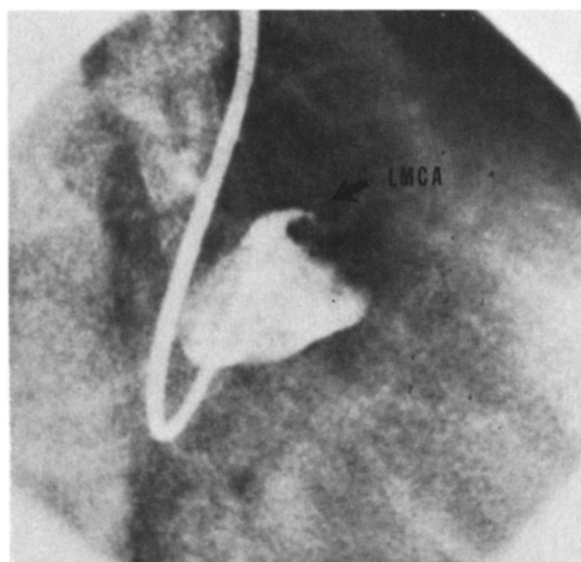


FIGURE 1. Angiographic appearance of totally occluded left main coronary arteries (LMCA) from coronary cineangiograms. **Top**, Case 4. Right anterior oblique view of a selective left coronary injection reveals gradual tapering to a complete occlusion. **Bottom**, Case 1. Left anterior oblique view of a left cusp injection reveals occlusion at the ostium.

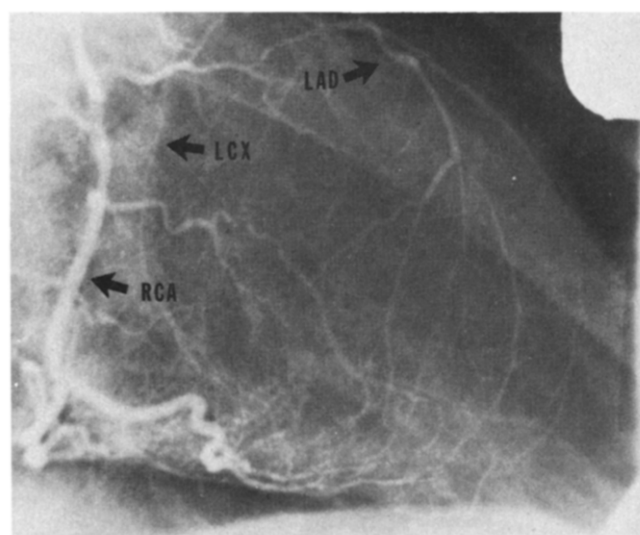


FIGURE 2. Case 2. Selective right coronary angiogram in the right anterior oblique view reveals a large right coronary artery (RCA) and copious collateral flow to the left coronary system. LAD = left anterior descending coronary artery; LCX = left circumflex coronary artery.

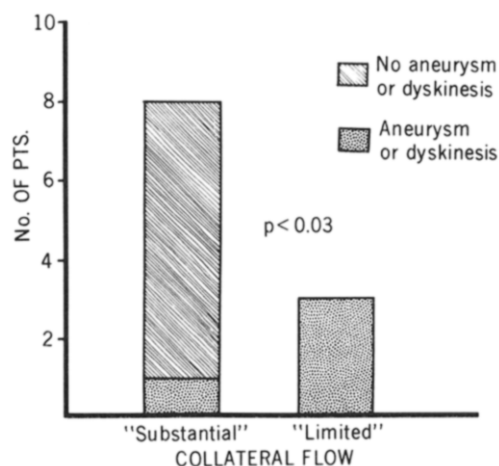


FIGURE 3. Relation of coronary collateral flow to left ventricular wall motion. "Substantial" collateral flow is associated with less severe wall motion abnormalities than in "limited" collateral flow. See text for definition of terms. p = probability.

TABLE IV

Follow-up Data in 12 Patients With Total Occlusion of the Left Main Coronary Artery

Case	CABG	Surviving	Months of Follow-Up (survival before death)	MI Since Entry	Most Recent Follow-Up	
					Angina (class)	CHF
1	+	+	23	—	—	—
2	+	+	48	—	—	—
3	+	+	59	—	—	—
4	—	+	42	+	+	+
5	—	—	(3.4)	—	—	—
6	+	+	36	—	+	—
7	—	+	48	—	—	—
8	+	+	48	—	+	—
9	+	—	(2)	—	—	—
10	—	—	(0.3)	—	—	—
11	+	+	60	—	—	—
12	—	—	(0.03)	—	—	—

* Anginal-like chest pain unrelated to activity.

CABG = coronary bypass graft surgery; CHF = congestive heart failure; MI = myocardial infarction; + = yes; — = no.

flow only one (13 percent) had an aneurysmal or dyskinetic left ventricular wall segment, compared with all three patients with "limited" collateral flow ($p < 0.05$) (Fig. 3). Although only three of the 8 patients with "substantial" collateral flow had 70 percent or greater stenosis of the right coronary artery, all three patients with "limited" collateral flow had at least one stenosis greater than or equal to 70 percent in the main channel of the right coronary artery.

Follow-up (Table IV): Of the 12 patients with total occlusion of the left main coronary artery, 8 were alive at their most recent follow-up examination, an average of 45 months (range 23 to 60) after entry into the CASS. Four patients died an average of 1.4 months after entry into the CASS. The mean age of entry in the study was 53.3 years for survivors and 70 years for nonsurvivors ($p < 0.05$). Seven of the eight survivors and all four of the nonsurvivors presented with angina pectoris. The duration of angina before entry into the study averaged 3.5 years in survivors and 6.1 years in nonsurvivors; the duration of the presenting level of symptoms was 0.26 year in survivors and 0.83 year in nonsurvivors. Neither of these differences is statistically significant.

Effect of surgery: The group of patients with total left main coronary artery occlusion who underwent coronary arterial bypass graft surgery was compared with the group that did not have surgery (Fig. 4). Of the seven surgically treated patients, six (86 percent) were alive at their most recent follow-up examination, a mean of 46 months after entry into the CASS. Only two of these patients continued to have angina pectoris, and none had sustained a myocardial infarction. In contrast, of the five patients not undergoing coronary bypass graft surgery, two (40 percent) were still alive a mean of 45 months after entry into the study. One of these medically managed patients was still having angina and this patient had also had a subsequent myocardial infarction. The difference in survival between the surgical and the nonsurgical group was not statistically significant. The coronary bypass graft surgery was performed

a mean of 6.7 days (range 1 to 20) after coronary angiography.

The one death among the patients who underwent coronary bypass graft surgery was due to a subarachnoid hemorrhage 61 days after entry into the CASS and 60 days after the surgery. Of the three patients who did not have coronary bypass graft surgery and who subsequently died, all died of cardiac causes a mean of 38 days after entry into the CASS.

The selection of patients for coronary surgery was not randomized. One patient had no symptoms so surgery was not recommended. One patient had a fatal cardiac arrest 1 day after catheterization while making her decision about the coronary bypass operation her physicians had recommended. Three patients were not considered surgical candidates because of small and diffusely diseased distal coronary arteries. Poor left ventricular function in one of these three patients and severe peripheral vascular disease in another also played a role in the clinicians' decisions. The mean age at the time of entry into the CASS was 56.0 years (range 45 to 74) for the surgical group and 62.8 years (range 44 to 80) for the nonsurgical group.

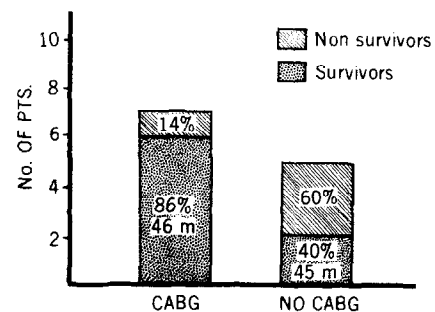


FIGURE 4. Mortality data for patients with total occlusion of the left main coronary artery grouped into those who underwent coronary bypass graft surgery (CABG) and those who did not. The length of follow-up time after entry into CASS is noted for the survivors. m = months.

Discussion

Prevalence: Total occlusion of the left main coronary artery was found in this study in 0.06 percent of the patients registered into the CASS who had no prior history of coronary surgery. Other reports³⁻¹⁷ of patients with this lesion have also documented its infrequent occurrence (from less than 0.01 to 0.4 percent of all patients undergoing cardiac catheterization at various centers). Mehta et al.¹⁰ found the left main coronary artery totally occluded in 6 (1 percent) of 625 patients with class III or IV angina or unstable angina pectoris evaluated by coronary angiography.

A separate analysis of the CASS data¹ and a study by Conley et al.² point out that patients with more severe degrees of left main coronary artery narrowing have a greater risk of death than do those with less severe obstruction. The highest grade of stenosis of an artery is total occlusion of the vessel. Conceivably, the low prevalence of patients with total left main coronary occlusion is due to the death of most people with this lesion before they undergo cardiac catheterization.

An alternate explanation for the rarity of total left main coronary occlusion rests on the observations of many workers^{9-11,21-23} that patients with atherosclerotic lesions in the left main coronary artery usually have similar lesions in other coronary arteries. Possibly the narrowing of these other coronary vessels in most patients with left main coronary artery disease causes death or leads to significant symptoms and a visit to a physician before a subtotal left main coronary arterial stenosis can progress to a complete occlusion.

Symptoms: Most patients with complete occlusion of the left main coronary artery in this study presented with severe angina of relatively long duration. This finding has been reported by others^{4,5,8,11-13,15-17}. However, historical features did not distinguish patients with total occlusion of the left main coronary artery in this series from those in the CASS with subtotal stenosis of this vessel. One patient (Case 7) did not have chest pain or a history of myocardial infarction (although left ventricular wall motion abnormalities were present). Goldberg et al.¹³ presented a somewhat similar patient with total occlusion of the left main coronary artery and only mild angina with severe exertion.

Coronary angiographic findings: Analysis of the left anterior descending and left circumflex coronary arteries revealed definite atherosclerotic lesions in three patients in this study as well as no apparent lesions in two patients. However, in the majority of patients angiographic visualization of the left coronary circulation was inadequate to define precisely the extent of lesions distal to the left main coronary artery. Possible explanations for this poor visualization include (1) a low volume of collateral flow from a diseased right coronary artery into the left coronary vessels, and (2) severe stenosis in the left coronary vessels that blocked the distribution of the collateral flow that was present.

In contrast, the right coronary artery was well seen in all cases. The degree of atherosclerosis in this vessel

was highly variable, with 7 of the 12 patients having at least one area of 70 percent or greater narrowing. A review of published cases of total left main coronary stenosis also reveals a broad spectrum of extent of right coronary artery disease. Although the three patients in our report with limited collateral flow had severe right coronary arterial stenosis, three of the eight with substantial collateral flow also had a major right coronary narrowing. These patients, whose entire myocardial blood supply must flow through a diseased right coronary artery, would appear to have a particularly high risk of myocardial infarction and death. In fact, the three patients in this series who had significant right coronary lesions (70 percent or greater narrowing) but did not undergo coronary bypass graft surgery all subsequently died within 3.4 months of enrollment in the CASS (Cases 5, 10 and 12).

Role of coronary collateral circulation: The importance of human coronary collateral circulation in providing myocardial flow is controversial.^{24,25} Although estimation of the quantity of collateral flow is imprecise, we considered it reasonable to separate patients with substantial collateral flow from those with limited collateral flow on the basis of whether or not at least part of the main channel of the left anterior descending or left circumflex coronary artery was well seen after contrast injection into the right coronary artery. We then found that the left ventricular wall motion was significantly better in patients with substantial than in those with limited collateral flow. Hamby et al.⁹ used a similar grading system for coronary collateral flow in evaluating patients with complete occlusion of the left anterior descending coronary artery. They found that "significant" collateral channels were associated with enhanced preservation of anterior left ventricular wall motion. These results indicate that coronary collateral vessels may be at least partially effective in supplying blood flow to ischemic myocardium.

Follow-up—role of coronary surgery: Of the seven patients with total occlusion of the left main coronary artery who underwent coronary bypass grafting, 6 (86 percent) are surviving at the time of this report. Only two have angina pectoris and none has had a subsequent myocardial infarction. In contrast, of those five patients treated medically only two (40 percent) are alive; one of these continues to have angina and this patient sustained a myocardial infarction during the follow-up period. However, the difference in survival between the surgical and nonsurgical groups did not reach statistical significance. In addition, the selection of patients for surgery was not randomized. The medical and surgical groups did not have comparable coronary anatomy or left ventricular wall motion. Hence, one cannot conclude with certainty that surgical therapy is the treatment of choice for patients with complete left main coronary arterial occlusion.

The five most recently reported series of patients with total occlusion of the left main coronary artery¹³⁻¹⁷ also document a good prognosis after coronary arterial surgery. A total of 19 patients in these series were treated

surgically and 17 were surviving at the time their cases were reported with the follow-up period ranging from 6 weeks to 5.5 years. Three patients were treated medically in these series and two were alive when their cases were reported 4 and 40 months after catheterization. Again, there was no attempt at randomization in these groups of patients. Thus, although surgical management has not been rigorously proved to be superior to medical treatment in patients with total occlusion of the left

main coronary artery, the favorable responses to operation in this and other series suggest coronary bypass graft surgery is a reasonable therapeutic option for patients with this uncommon lesion.

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APPENDIX

Operating Clinical Sites

University of Alabama in Birmingham: William J. Rogers, MD,* Richard O. Russell, Jr., MD, Albert Oberman, MD, Nicholas T. Kouchoukos, MD. **Albany Medical College:** Julio A. Sosa, MD,* Martin F. McKneally, MD,* Thomas Older, MD, Eric Foster, MD, Joseph McIllduff, MD. **Loma Linda University:** Melvin P. Judkins, MD,* Patrick M. Moloney, MD. **Boston University:** Thomas J. Ryan, MD,* Robert L. Berger, MD, Laura Wexler, MD, David P. Faxon, MD, Donald A. Wiener, MD. **Marshfield Clinical Foundation for Medical Research and Education:** William Myers, MD,* Richard D. Sautter, MD,* John N. Brownell, MD, Dieter M. Voss, MD, Robert D. Carlson, MD. **Massachusetts General Hospital:** J. Warren Harthorne, MD,* W. Gerald Austen, MD, Robert Dinsmore, MD, Frederick Levine, MD, John McDermott, MD, Frederick Poulin, MD. **Mayo Clinic and Mayo Foundation:** Robert L. Frye, MD,* Hugh C. Smith, MD, Ronald E. Vliestra, MD, Richard Fulton, MD. **Miami Heart Institute:** Arthur J. Gosselin, MD,* Parry B. Larsen, MD, Paul Swaye, MD. **Montreal Heart Institute:** Martial G. Bourassa, MD,* Jacques Lesperance, MD, Bernard R. Chaitman, MD, Claude Goulet, MD, Claude M. Grondin, MD. **New York University:** Ephraim Glassman, MD,* Michael Schloss, MD, O. Wayne Isom, MD. **St. Louis University:** George Kaiser, MD,* J. Gerard Mudd, MD,* Hendrick B. Barner, MD, John E. Codd, MD, Hillel M. Laks, MD, Denis

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Chairman of Steering Committee

Henry Ford Hospital, Detroit, Michigan: Thomas Kilip, MD

National Heart, Lung, and Blood Institute

Michael B. Mock, MD; Ivar Ringqvist, MD; Peter Frommer, MD

References

1. Chaitman BR, Fisher L, Bourassa MG, et al. Effect of coronary bypass surgery on survival patterns in subsets of patients with left main coronary disease. *Am J Cardiol* 1981;48:765-77.
2. Conley MJ, Ely RL, Kisslo J, Lee RK, McNeer JF, Rosati RA. The prognostic spectrum of left main stenosis. *Circulation* 1978;57:947-52.
3. Reul GJ, Morris GC Jr, Howell JF, Crawford S, Wukasch DC, Sandford FM. Coronary artery bypass in totally obstructed major coronary arteries. *Arch Surg* 1971;102:373-9.
4. Crochet DP, Campeau L, Saltiel J. Profil et evolution de l'obstruction complete du tronc commun de al coronaire gauche. *Ann Cardiol Angeiol* 1974;23:333-40.
5. Kershbaum KL, Manchester JH, Shelburne JC. Complete left coronary obstruction. *Chest* 1973;64:539-40.
6. Khaja F, Sharma SD, Easley RM, Heinle RA, Goldstein S. Left main coronary artery lesions. Risks of catheterization; exercise testing and surgery. *Circulation* 1974;49, 50:Suppl II:113-40.
7. Lim JS, Proudfit WL, Sones FM Jr. Left main coronary arterial obstruction: long-term follow-up of 141 nonsurgical cases. *Am J Cardiol* 1975;36:131-5.
8. Sutherland RD, Allison W, Guynes WA, Martinez HE. Complete obstruction of the left main coronary artery associated with congenital pulmonary valvular stenosis. *Chest* 1976;69:238-9.
9. Hamby RI, Aintablain A, Schwartz A. Reappraisal of the functional significance of the coronary collateral circulation. *Am J Cardiol* 1976;38:305-9.
10. Mehta J, Hamby RI, Hoffman I, Hartstein ML, Wisoff BG. Medical-surgical aspects of left main coronary artery disease. *J Thorac Cardiovasc Surg* 1976;71:137-41.
11. Nili M, Vidne BA, Wurtzel M, Levy MJ. Complete occlusion of the left main coronary artery: successful surgical management by myocardial revascularization. *Israel J Med Sci* 1977;13:1118-22.
12. Frye RL, Gura GM, Chesebro JH, Ritman EL. Complete occlusion of the left main coronary artery and the importance of coronary collateral circulation. *Mayo Clin Proc* 1977;52:742-5.
13. Goldberg S, Grossman W, Markis JE, Cohen MV, Baltaxe HA, Levin DC. Total occlusion of the left main coronary artery. A clinical, hemodynamic and angiographic profile. *Am J Med* 1978;64:3-8.
14. Greenspan M, Iskandrian AS, Segal BL, Kimbiris D, Bemis CE. Complete occlusion of the left main coronary artery. *Am Heart J*

* Denotes Principal Investigator.

- 1979;98:83-6.
15. **Crosby IK, Wellons HA Jr, Burwell L.** Total occlusion of left coronary artery. Incidence and management. *J Thorac Cardiovasc Surg* 1979;77:389-91.
16. **Valle M, Virtanen K, Hekall P, Frick MH.** Survival with total occlusion of the left main coronary artery: significance of the collateral circulation. *Cathet Cardiovasc Diagn* 1979;5:269-75.
17. **Trnka KE, Febres-Roman PR, Cadigan RA, Crone RA, Williams TH.** Total occlusion of the left main coronary artery: clinical and catheterization findings. *Clin Cardiol* 1980;3:352-5.
18. **Kronmal RA, Davis K, Fisher LD, Jones RA, Gillespie MJ.** Data management for a large collaborative clinical trial (CASS). *Comput Biomed Res* 1978;11:553-66.
19. **Killip TM, Fisher LD, Mock MB (eds).** National Heart, Lung, and Blood Institute Coronary Artery Surgery Study. *Circulation* 1981;63:Suppl I:I-1-81.
20. **Campeau L.** Grading of angina pectoris (letter). *Circulation* 1976;54:522-3.
21. **Cohen MV, Gorlin R.** Left main coronary artery disease. Clinical experience from 1964-1974. *Circulation* 1975;52:275-85.
22. **Talano JV, Scanlon PJ, Meadows WR, Kahn M, Pifarre R, Gunnar RM.** Influence of surgery on survival in 145 patients with left main coronary artery disease. *Circulation* 1975;51,52:Suppl I:I-105-11.
23. **Bulkley BH, Roberts WC.** Atherosclerotic narrowing of the left main coronary artery. A necropsy analysis of 152 patients with fatal coronary heart disease and varying degrees of left main narrowing. *Circulation* 1976;52:823-8.
24. **Gregg DE, Patterson RE.** Current concepts: functional importance of coronary collaterals. *N Engl J Med* 1980;303:1404-6.
25. **McGregor M.** The coronary collateral circulation. A significant compensatory mechanism or a functional quirk of nature? *Circulation* 1975;52:529-30.